CONNECTING GAP ACCEPTANCE BEHAVIOR WITH CRASH EXPERIENCE

Steven M. Tupper, Graduate Research Assistant, Department of Civil and Environmental Engineering, University of Massachusetts Amherst,
Amherst, MA, USA, e-mail: stevenmtupper@gmail.com

Michael A. Knodler Jr., Associate Professor, Department of Civil and Environmental Engineering, University of Massachusetts Amherst,
Amherst, MA, USA, e-mail: mknodler@ecs.umass.edu

David S. Hurwitz, Assistant Professor, School of Civil and Construction Engineering, Oregon State University,
Coravllis, OR, USA, e-mail: david.hurwitz@oregonstate.edu

ABSTRACT

While a basic understanding of drivers' gap acceptance behavior may be understood, many unanswered questions remain, particularly regarding the safety-related impacts associated with this behavior. Previous work has attempted to address these questions, yet limitations in scope have continually emerged as a result of challenges associated with the collection of high fidelity gap acceptance data in the field. This research directly addresses the safety-related implications of driver's gap acceptance behavior with a large-scale data collection effort of detailed gap acceptance data.

Using the data set collected in the large-scale field test using a newly developed software package, factors that appeared to affect drivers' gap acceptance decision-making, and had clear implications on safety, were identified. Different driver groups, specifically different age and gender groups, displayed different gap acceptance behavior. The factors that had the greatest affect on gap acceptance behavior were the presence of a queue behind the driver, driver wait time, and number of gaps rejected. These factors, relating to drivers feeling pressure or simply impatience, resulted in drivers accepting shorter gaps and sacrificing a degree of safety to execute their turn.

Identifying and analyzing "gap acceptance related" crashes, connections were drawn with the results of the gap acceptance analysis. Driver groups displaying more aggressive gap acceptance behavior, male drivers and teen drivers, are overrepresented in gap acceptance related crashes. Development of a better understanding of these connections has the potential to translate into more targeted solutions to the gap acceptance related crash problem.

Keywords: Gap acceptance, critical gap, driver behavior, human factors, safety

INTRODUCTION

In the field of transportation safety it is well understood that crashes can be attributed to failures of the road, the vehicle, the user, or some combination thereof. One common driving task that requires each of these elements exists when drivers are tasked with making a gap acceptance decision either merging into or crossing a lane of traffic.

Given that "driver error" is cited as a contributing factor in 93 percent of all crashes, understanding driver behavior is an essential element in mitigating the crash problem (Transportation Research Board 2003). Among the more dangerous roadway elements are unsignalized intersections where driver behavior is directly related to the operational and safety performance (Transportation Research Board 2003). More specifically, drivers' gap acceptance decisions have serious consequences, and in many situations, the result of a poor gap acceptance decision is a crash.

The process of a driver's gap acceptance decision is driven by an individual's goals and attitudes and is affected by stimuli from their surroundings. It is widely accepted that the best method of observing naturalistic driver behavior is through field investigation (Daganzo 1981). The difficulty is that current data collection methods are limited in the quality and quantity of data that can be reasonably gathered.

Problem Statement

A need exists to foster a greater understanding of drivers' gap acceptance behavior based upon real-world empirical data. Understanding this aspect of driver behavior is critical to transportation professionals dealing with roadway design and safety.

The mostly commonly used metric of drivers' gap acceptance behavior is critical gap, defined by the Transportation Research Board (2000) as, "the minimum time interval in the major-street traffic stream that allows intersection entry for one minor-street vehicle." In practice, transportation professionals utilize standard default values of critical gap, as reported in the *Highway Capacity Manual 2000*, and apply a few basic corrections factors to reflect the site specific conditions. The problem with this current method is two-fold. First, the correction factors only account for a few basic factors that are likely to affect gap acceptance behavior. Some of the arguably most influential factors, such as local driver demographics, are not included. Many studies have found that factors such as driver age and sex (Zhou, et al. 2010, Wu 2006, X. Yan, et al. 2003, Yan, Radwan and Guo 2006, Leung and Starmer 2005) have a significant effect on drivers' gap acceptance behavior. Second, the standard values of critical gap, as well as the correction factors, are based on a relatively limited number of small-scale studies. In order to develop a greater understanding of drivers' gap acceptance behavior a large-scale field investigation must be undertaken.

Inaccurate or incorrectly used information on how drivers utilize gaps in traffic can lead to inappropriate design decisions. If overly passive gap acceptance behavior is assumed

(large critical gap), roadway elements will be overdesigned thus wasting money, compromising efficiency, and possibly having deleterious effects on other elements of the roadway system. If overly aggressive gap acceptance behavior is assumed (small critical gap), the results will be a design that has insufficient capacity for turning movements and can even force drivers to make gap acceptance decisions in dangerous situations. Having access to a more accurate estimate of critical gap that accurately reflects the conditions under which it is be applied would lead to safer and more efficient roadway design.

When drivers make poor gap acceptance decisions there is a strong likelihood that the result will be a crash. The resulting crashes, often angle crashes, are some of the most severe crashes (Transportation Research Board 2003). Few studies exist on crashes related to poor gap acceptance decisions, but those that have been completed have begun to shed light at some of the underlying causes (Caird 2002). Ultimately, a better understanding of the driver and environmental factors that significantly contribute to increased crash risk will help guide the way to targeted design solutions.

Despite the critical nature of this data, to date, there have not been any large-scale studies due mostly to the inherent challenges of collecting such data. To this end, the research initiative proposed uses of a new data collection tool that allows for the collection of large, high-fidelity data sets on gap acceptance behavior. Having access to this tool, transportation researchers will have the ability to collect larger, more detailed samples in the field in a relatively cost effective and timely manner.

Research Objectives

Based upon the existing research needs and the potential for utilizing data collected using a newly developed data collection tool, a pair objectives for the research initiative were proposed. The overarching goal of this research effort was to improve the understanding of driver behavior elements as related to gap acceptance. The following objectives were established to address aims of this research initiative:
- Identify differences in gap acceptance behavior across drivers under varied conditions in the field; and
- Determine the extent to which differences in drivers' gap acceptance have implications on correlations to safety effects that can be seen in crash data.

STUDY DESIGN AND METHODOLOGY

In an effort to achieve the established research objectives a large-scale field study was completed by over a dozen team members in Massachusetts and Oregon. In total 60 sites, 2,767 drivers, 10,419 driver decisions, and 22,639 gaps in traffic were observed. The observations were focused on left and right turning maneuvers at unsigalized T-intersections. The data was collected over the course of a year varying both day of day (weekdays only for this phase of analysis) and time of day (daylight only due to visibility requirements). These observations represent a wide array of site conditions, under various traffic conditions, by many different drivers. For this phase of study each

intersection was sampled once. The next phase of the study will involve sampling the same sites multiple times to test temporal variations.

The field study utilized a newly developed program that can be operated by one person on a laptop computer in the field. A second observer is required if detailed vehicle and driver characteristics are to be simultaneously collected, which was done during the field study relating to this research initiative. To ensure that the results of the field study were accurate, a prior video validation was performed (Tupper 2011).

Once gap acceptance data has been compiled there remain a myriad of methods by which overall analyses of gap acceptance, and critical gap analyses in particular, can be completed. For this research initiative three different methods, the Raff Method, the Cumulative Acceptance Method, and the Fit Maximization Method, were used. One of the most commonly used methods in practice, the Raff Method, identifies the critical gap as the gap length where drivers are equally likely to accept or reject the gap. A method described in some data collection manuals, the Cumulative Acceptance Method, identifies the critical gap as the gap length that would be accepted by 85 percent of drivers (Currin 2001). The Fit Maximization Method identifies the critical gap that maximizes the number of rejected gaps smaller than the critical gap and maximizes the number of accepted gaps larger than the critical gap. These methods are all based in strong logic, relative ease of use, and provide an estimate of the critical gap, a key parameter in the analysis of gap acceptance data, that are close to values listed in the *Highway Capacity Manual 2000* (Tupper 2011).

Analysis by Factor

There are a number of variables that influence a driver's gap acceptance behavior. Many factors are associated with the specific site such as the number of lanes, speed limit, functional classification, type of traffic control device, and traffic volume on the minor and major streets. Other factors are associated with the driver such as the driver's gender, age, the type of vehicle they are driving, and whether or not they have passengers in the vehicle. Additional factors believed to affect gap acceptance behavior relate to other conditions present at the moment the decision is being made such as weather, time of day, presence of vehicles queued behind the turning vehicle, and length of wait time. As part of the analysis associated with this research objective, gap acceptance behavior, and in particular critical gaps, were compared when considering a these various factors. As noted previously, a combination of data collected in Massachusetts and Oregon was used for the analysis. Please note that a majority of the data collection used in this analysis was completed in Massachusetts and supplemented with additional data from Oregon when it was collected in a similar format at comparable location types.

Connecting Driver Behavior to Crash Experience

With the understanding that differences in driving behavior between different driving populations, the question that arises is whether or not these differences in behavior result in different levels of driver risk on the roadway. For example, if driving group display

particularly aggressive or erratic gap acceptance behavior does this correspond to an increased crash rate on the roadway?

To address the research questions related to this research objective "gap acceptance related" crashes from were identified from crash data within the UMass Safety Data Warehouse, housed at the University of Massachusetts Traffic Safety Research Program (UMassSafe). The crashes considered included those with characteristics that match the conditions under which the gap acceptance data was collected. Specifically crashes occurring at an unsignalized T-intersection where a vehicle was making a left or right hand turn were queried and initially considered. The crashes were further narrowed by those where a driver was cited for an intersection right of way violation, an indication of inappropriate gap acceptance behavior (Caird 2002). To ensure that the crashes were related to gap acceptance issues, the crash narratives, as written on the crash reports, were further examined.

A subsequent analysis was then performed to determine which driving groups were overrepresented in gap acceptance related crashes. Connections were made between the gap acceptance behavior of different driving groups and their relative representation in gap acceptance related crashes.

RESULTS AND ANALYSIS

As noted, it is widely accepted that there are a number of variables that influence a driver's gap acceptance behavior. These factors can be organized into driver/vehicle characteristics, site characteristics, and additional factors related to conditions at the time of the turn. Such factors thought to affect gap acceptance behaviors are presented in Table 1. The highlighted factors in Table 1 will be discussed in detail within this section, as they both demonstrated profound effects on gap acceptance behavior and have clear safety implications. The remaining factors are being analyzed in other research initiatives currently underway, but had a lesser impact in addressing the research question associated with this research effort.

Table 1. Factors Thought to Affect Gap Acceptance Decisions

Driver/Vehicle Characteristics	Site Characteristics	Additional Factors
Driver Gender	Major and Minor Street Speed Limit	Time of Day
Driver Age	Major and Minor Street Lane Configuration	Day of Week
Passenger Presence	Major and Minor Street Functional Class	Queue Presence
Vehicle Type	Major and Minor Street Traffic Control Device	Wait Time
Driver Decision Making Ability	Major and Minor Street Traffic Volumes	Number of Rejected Gaps
	Sightline Restrictions	Weather

For analysis purposes, the turning maneuvers were considered at the aggregate level including both left and right turning maneuvers as both maneuvers showed the same

trends. By including both maneuvers the comparisons could be completed in a more concise and easy to interpret manner while simultaneously drawing upon the largest possible sample size for comparison. Where possible, the effects of different characteristics were compared using the Raff, Cumulative Acceptance, and Fit Maximization Methods that where discussed previously. Chi Square tests were then used to statistically compare the distributions for the percentage of gaps accepted across variable levels to determine the extent to which differences were significant.

Driver Gender

Driver gender has shown mixed effects in other research initiatives, however this trend continued with this research initiative. While Table 2 presents differences between the critical gaps estimated by each method, the Chi-Square Test showed no statistically significant differences between the gap acceptance distributions.

Table 2. Effect of Driver Gender on Gap Acceptance Behavior

Critical Gap Analysis Method	Male	Female	Difference
Raff Method [s]	5.5	6.0	0.5
Cumulative Acceptance Method [s]	6.0	6.25	0.25
Fit Maximization Method [s]	5.25	6.0	0.75
Chi-Square Test p-Value	p=0.573, no statistically significant difference		

The lack of statistically significant does not necessarily mean that driver gender plays no role in driver gap acceptance behavior, only that the overall distributions are similar. The distributions are in fact very similar, as shown in Figure 1, for large and smaller gaps, yet in the region where the most driver uncertainty occurs, between five and seven seconds, male drivers appear to be more aggressive. Further sampling across the nation should be conducted to see if these trends are representative of the entire driving population.
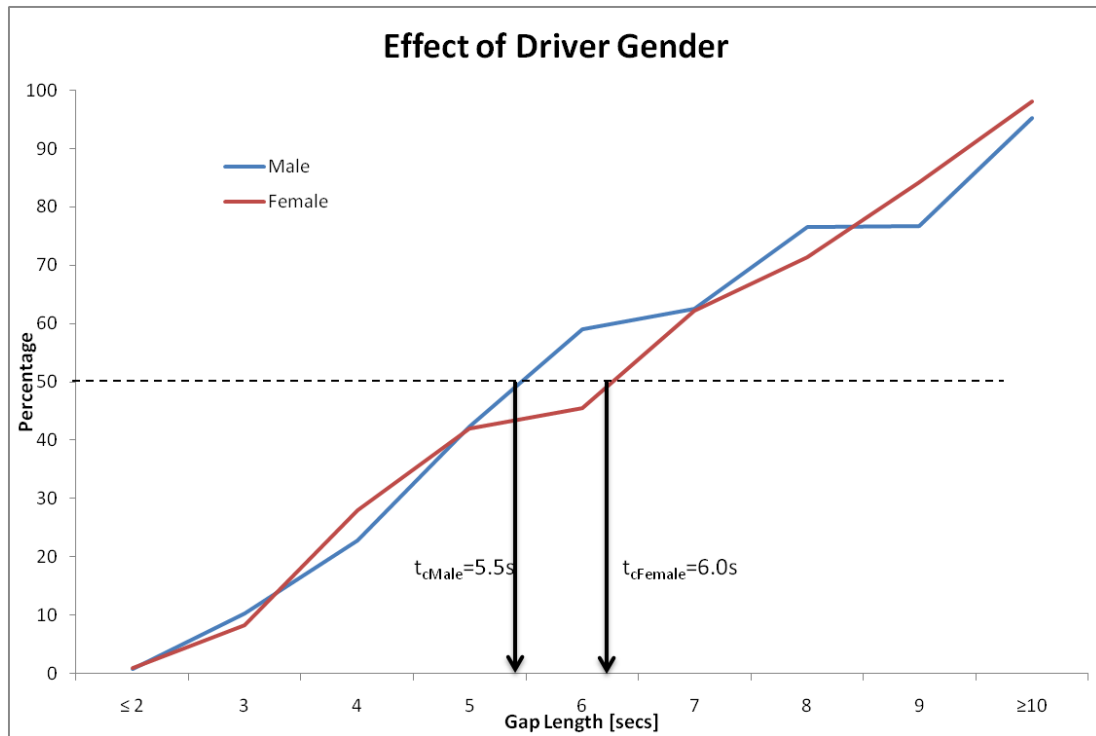
Figure 1. Effect of Driver Gender on Gap Acceptance Behavior

Driver Age

This research initiative has shown significant differences in gap acceptance behavior between different age groups. As presented in Table 3, both practical and statistically significant differences exist in gap acceptance behavior between all age groups studied.

Table 3. Effect of Driver Age on Gap Acceptance Behavior *

Critical Gap Analysis Method	Teen	Adult	Elderly
Raff Method [s]	5	6	5.5
Cumulative Acceptance Method [s]	3.75	5.25	6
Fit Maximization Method [s]	5	6.25	5.75
Chi-Square Test p-Value (Teen vs. Adult)	$p \ll 0.05$, statistically significant difference		
Chi-Square Test p-Value (Elderly vs. Adult)	$p=0.021$, statistically significant difference		

*included Oregon Data

The differences are most notable between the teen and adult driver. To a very high degree of certainty, the gap acceptance distributions are significantly different between these two age groups. The estimates of critical gap show similar differences between the teen and adult groups. All indications are that teens display more aggressive gap acceptance behavior than adults.

The differences are less notable between the adult and elderly driver groups. Additionally, it is unclear exactly what overall difference may exist. Some analysis methods suggest the adult driver is more aggressive while others suggest the elderly

driver is more aggressive. A larger sample of elderly drivers is required for definitive conclusions to be drawn.

Figure 2 presents the gap acceptance curves for teen, adults, and elderly drivers. The same relative trends previously discussed are apparent with the gap acceptance distribution curves. The teen drivers show clearly more aggressive gap acceptance behavior than adult drivers. The difference between the adult and elderly driver groups is less clear.
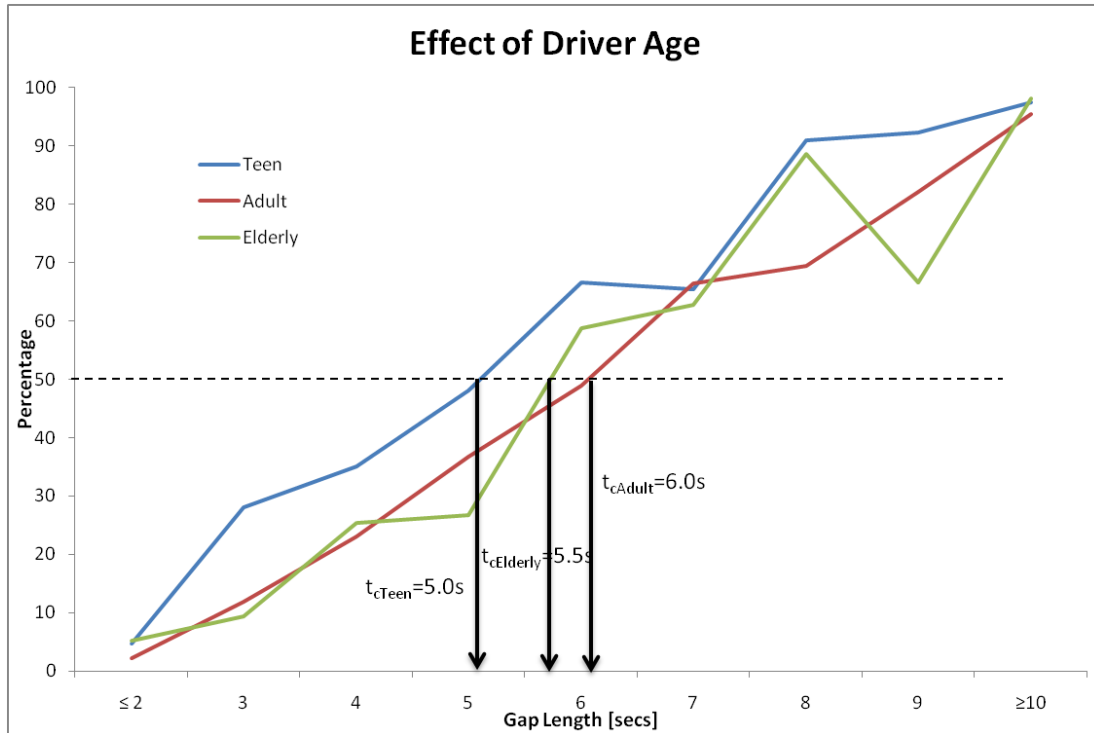

Figure 2. Effect of Driver Age on Gap Acceptance Behavior

Passenger Presence

The extent to which a driver's gap acceptance behavior varies when based upon the presence of passengers in the vehicle has not been rigorously studied. An initial hypothesis might suggest that drivers may be more cautious knowing that they are responsible for the lives of others within their vehicles. Another would suggest that drivers, especially young drivers, may be distracted or pressured by passengers in the car to act more aggressively. In this research initiative the later was observed. As Table 4 shows, drivers act more aggressively, accepting smaller gaps, when passengers are present in the vehicle. While the difference in the gap acceptance distributions were not quite statistically significant, the differences in the critical gap estimate were practically significant. With differences in critical gap ranging from 1.0 to 1.5 seconds, this condition showed some of the greatest effects of the factors studied in this research initiative.

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Table 4. Effect of Passenger Presence on Gap Acceptance Behavior

Critical Gap Analysis Method	Passengers	No Passengers	Difference
Raff Method [s]	5.0	6.0	1.0
Cumulative Acceptance Method [s]	5.25	6.5	1.25
Fit Maximization Method [s]	4.5	6.0	1.5
Chi-Square Test p-Value p-Value	p=0.068, approaching statistical significance		

The gap acceptance curves for drivers both with and without passengers in the vehicle, presented in Figure 3, illustrate the identifiable difference in behavior between the two conditions. The range from three to seven seconds, where almost all true gap acceptance decisions take place, drivers with one or more passengers were more aggressive than drivers without any passengers.
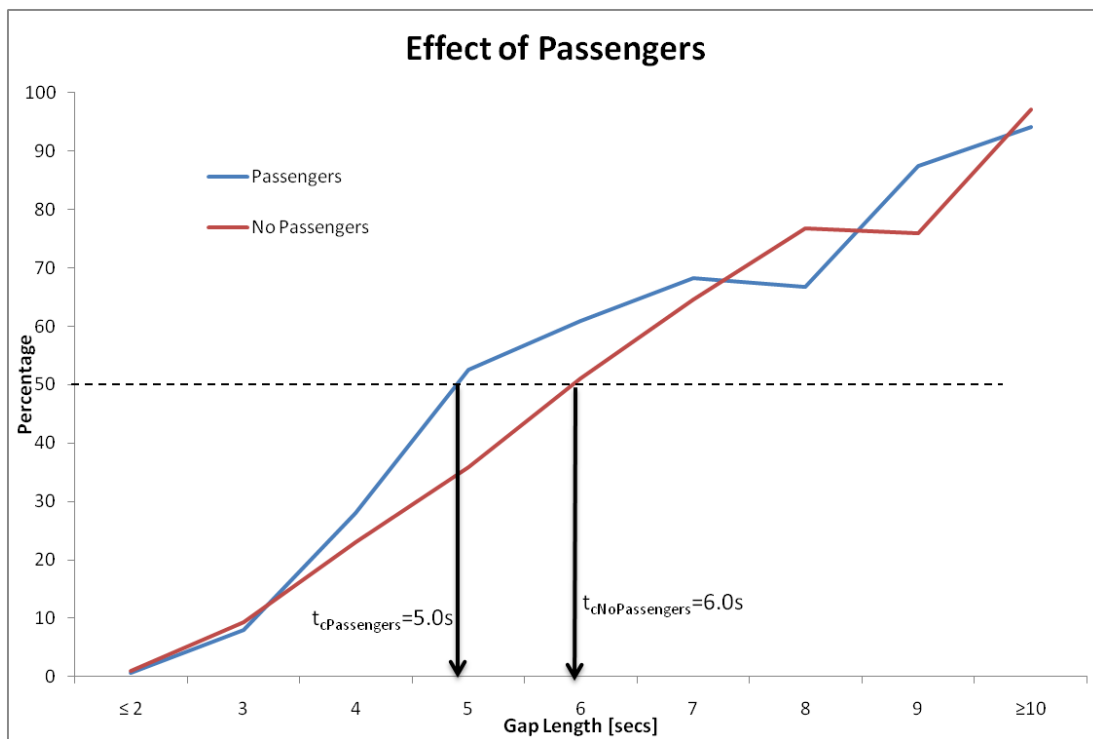

Figure 3. Effect of Passenger Presence on Gap Acceptance Behavior

Time of Day

There has long been a belief that drivers are more aggressive during the AM and PM peak periods when they are commuting to and from work. As a result all actions observed during the field study were time stamped so that they could easily be organized by time period. The gap acceptance behavior was compared for the AM Peak, defined as 7-9 AM, the PM Peak, defined as 4-6 PM, and Midday, defined as 10 AM - 2 PM. The results of this comparison are presented in
Table 5 and Figure 4.

Table 5. Effect of Time of Day on Gap Acceptance Behavior

Critical Gap Analysis Method	AM Peak (7-9 AM)	PM Peak (4-6PM)	Midday (10AM-2PM)
Raff Method [s]	6.5	6	5
Cumulative Acceptance Method [s]	4	4.25	6
Fit Maximization Method [s]	5	5.75	5.5
Chi-Square Test p-Value (Between All Sets)	p<<0.05, statistically significant difference		

As the estimates of critical value suggest, drivers are most aggressive during the AM and PM Peaks than during the Midday time period. Figure 4 presents similar results, although though there is a decrease in the AM Peak curve at six seconds that skews the Raff Method critical gap estimate; this difference most likely a sample size issue.
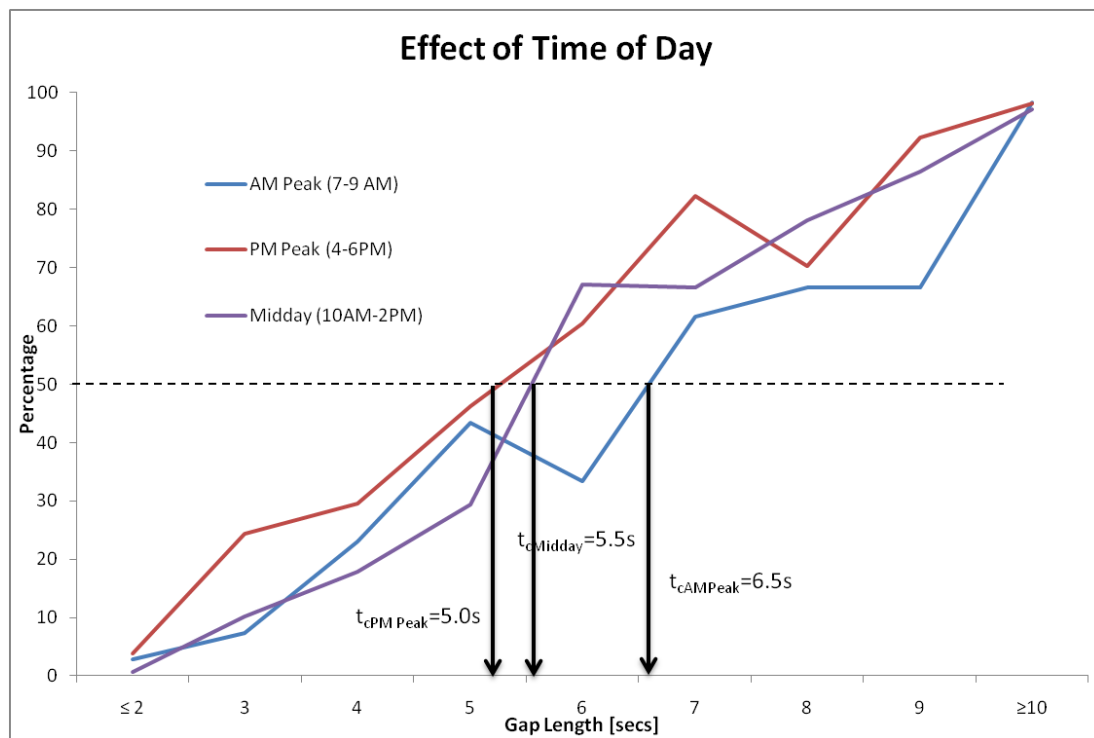

Figure 4. Effect of Time of Day on Gap Acceptance Behavior

Queue Presence

One of the more interesting results from this research initiative related to a change in driver behavior when there are vehicles queued up behind the driver. While the gap data was being observed in the field, the second observer took note of how many vehicles were queued up behind the vehicle exiting the minor street when the driver made the turning maneuver. For analysis, the cases where a queue was present and where no queue was present were compared. These results are presented in Table 6.

Table 6. Effect of Queue Presence on Gap Acceptance Behavior

Critical Gap Analysis Method	No Queue	Queue Present	Difference
Raff Method [s]	6.0	4.5	1.5
Cumulative Acceptance Method [s]	6.5	5.25	1.25
Fit Maximization Method [s]	6.0	4.5	1.5
Chi-Square Test p-Value	p<<0.05, statistically significant difference		

By all three analysis methods utilized, the estimated critical gap when a queue is present was much shorter than when no queue was present. The gap acceptance distributions of these to conditions were shown to be different at a very high level of statistical significance.

This trend is even more pronounced when examining the gap acceptance curves presented in Figure 5. For all but the smallest and largest gaps, a greater percentage of gaps were accepted when a queue was present.
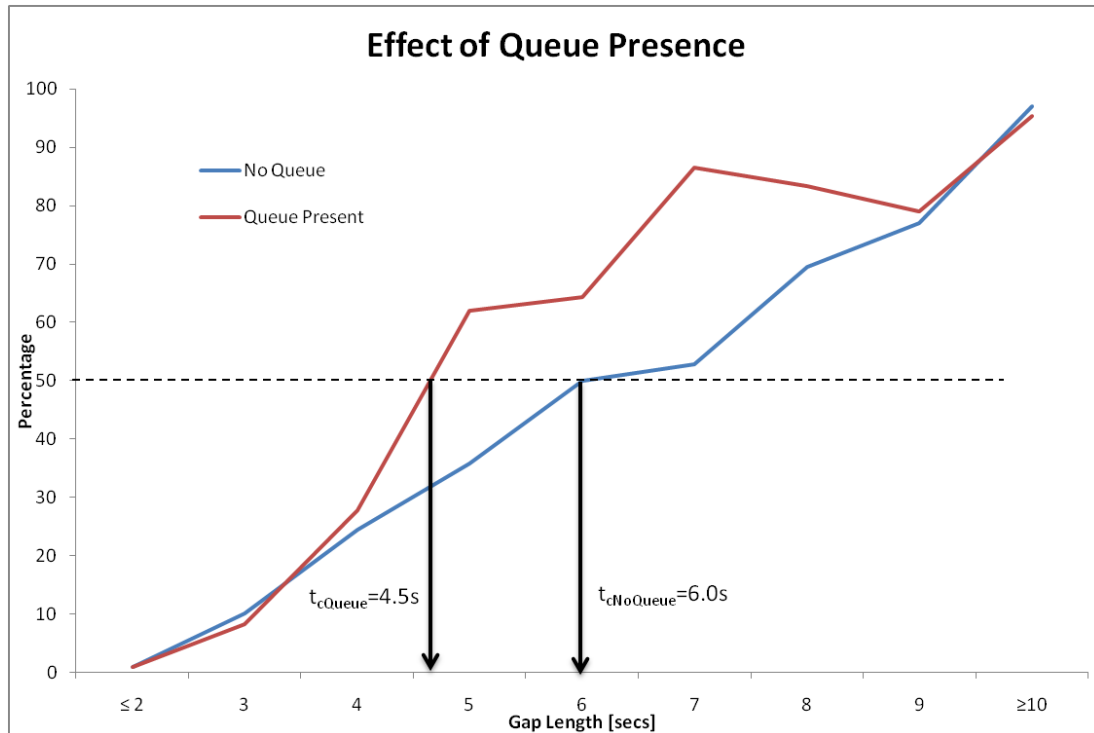

Figure 5. Effect of Queue Presence on Gap Acceptance Behavior

These results provide evidence to suggest that drivers who have vehicles queued up behind them will accept shorter gaps. The drivers likely feel pressured by the vehicles behind them and therefore are willing to accept a gap smaller than they normally would. This behavior has clear implications from a safety standpoint as well. The pressure drivers feel when vehicles are queued up behind them may lead them to sacrifice some measure of safety to complete their desired turning maneuver. The implication of this result highlights a challenge and an opportunity for transportation professionals responsible for intersection design. For example, an uncontrolled intersection identified

as having excessive queuing, may also have a resulting safety issue. Yet the extent to which remedial measures can be identified and implemented may translate into improved operational efficiency and safety.

Wait Time

As any driver is likely to attest, if one has beenwaiting a long to time to complete a turn you may start thinking about accepting a gap smaller than you normally would. According to the results of this study, drivers not only think about selecting a smaller gap, but do in fact select a smaller gap after waiting for an extended period of time.

Using the time stamped action data from the field study, the amount of time each vehicle waited before turning was calculated. For analysis purposes these wait time were aggregated into four intervals: less than 10 seconds, 10 to 20 seconds, 20 to 30 seconds, and greater than 30 seconds. The Cumulative Acceptance Method was then used to estimate the critical gap for turning maneuvers that fell into each of these four categories. The results of this analysis are presented in Figure 6.
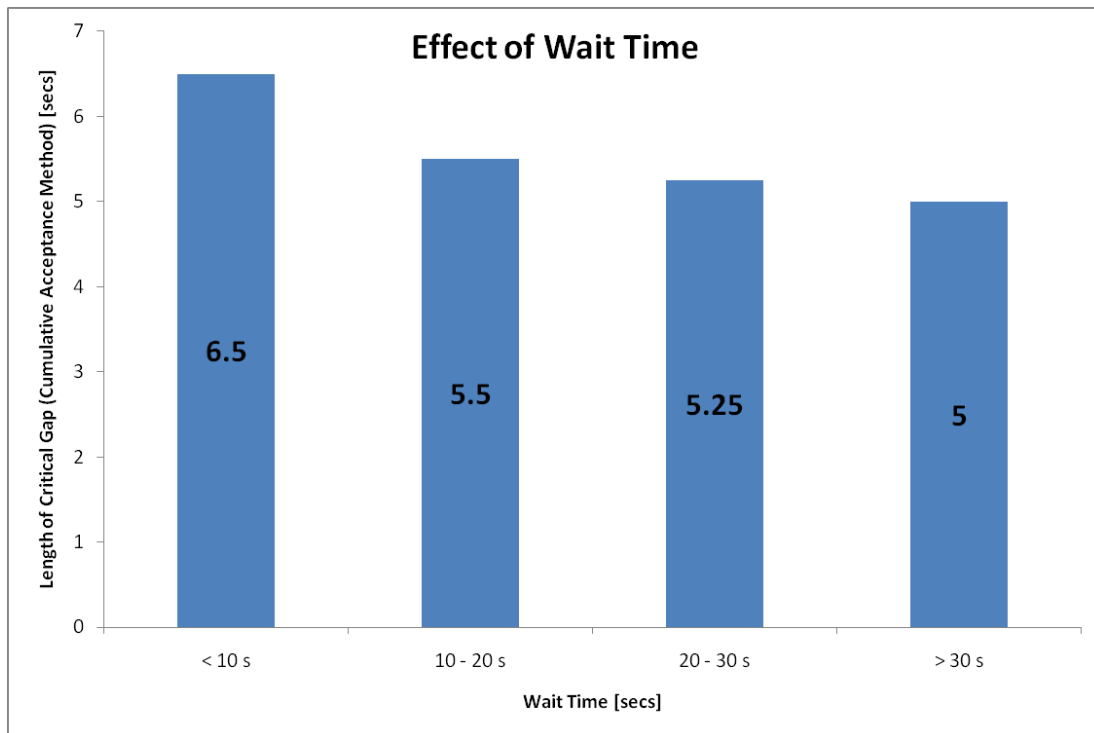

Figure 6. Effect of Wait Time on Critical Gap

As presented in Figure 6, drivers were willing to accept smaller gaps as the amount of time they had been waiting increased. This falls in line with initial hypotheses which suggest that drivers are willing to sacrifice a bit of safety as they become impatient. As a result, it is clear that conditions that result in drivers having to wait long periods of time result in safety risks. Once again remediation measures that reduce wait times could improve efficiency as well as safety.

Number of Rejected Gaps

Closely related to wait time is the number of gaps the drivers rejects. As the driver waits from an acceptable gap they reject more and more gaps. As the number of gaps that they have rejected increases they are likely to become more impatient and possibly accept a smaller gap.

Aggregating the field data by the number of gaps the driver rejected, conclusions could be drawn. As with wait time, the Cumulative Acceptance Method was used to estimate the critical gap for turning maneuvers that feel into each category. Figure 7 presents the results of this analysis.
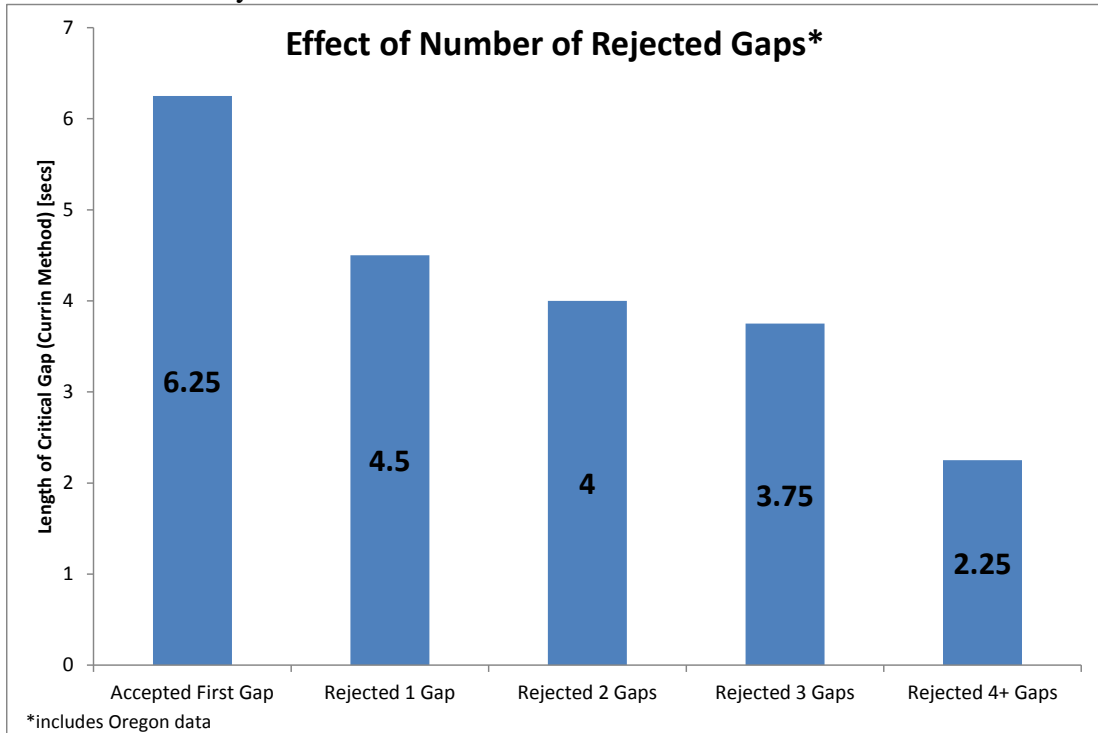

Figure 7. Effect of Number of Rejected Gaps on Critical Gap

As presented in Figure 7, drivers were willing to accept smaller gaps as the number of gaps they rejected increased. As with the wait time analysis, this falls in line with expectations and suggests that drivers are willing to sacrifice a bit of safety as they become impatient. Where drivers are subject to the frustration of having to reject gap after gap, a safety risk clearly exists.

Connecting Driver Behavior to Crash Experience

As described in the methodology section, data from the UMass Safety Data Warehouse was used in combination with the field data during this research initiative. The crash, citation, and other relevant data were accessed from various agencies through the UMass Safety Data Warehouse, which was developed as a tool for maximizing the use of highway safety data. Data available from the Warehouse include traditional datasets, such as crash and citation data, as well as less traditional highway safety information,

such as health care data and commercial vehicle safety data. The use of assorted, diverse data allows for truly comprehensive analyses of highway safety problem areas. The accompanying schematic shows the variety of data that is available in the UMass Safety Data Warehouse. For purposes of the current research initiative the data were analyzed to understand the nature of the crash and relative differences between age and gender groups.

In order to identify crashes within the Data Warehouse related to gap acceptance a process was developed for this research initiative to identify "gap acceptance related crashes." To maintain a manageable sample size crashes occurring in Massachusetts between 2007 and 2009 were analyzed. The crashes considered were those with characteristics that matched the conditions under which the gap acceptance data was collected; occurring at an unsignalized T-intersection where a vehicle was making a left or right hand turn. To ensure that the crashes were related to gap acceptance issues, the crashes were further narrowed by those where a driver was cited for an intersection right of way violation, an indication of inappropriate gap acceptance behavior (Caird 2002).

The gap acceptance related crash identification process narrowed the data set from a total of 93,253 crashed to 156 crashes related to gap acceptance as shown in Figure 8.
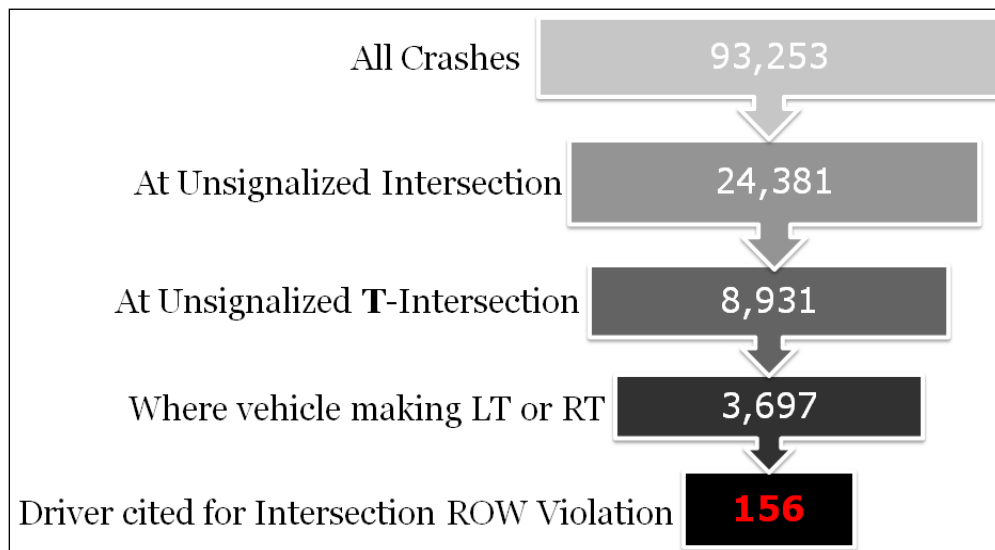

Figure 8. Identifying Gap Acceptance Related Crashes (Massachusetts 2007-09)

To ensure that the 156 remaining crashes were indeed gap acceptance related crashes the crash narratives, as recorded on the crash reports were reviewed. The crash narratives were quite telling as to the circumstances of the crash. One crash narrative reads:

> *Vehicle 2 was traveling east on Main St. when vehicle 1 pulled out onto Main St. from Harrington **cutting in front of** vehicle 2 causing a collision.*

For whatever reason, the driver of vehicle 1 accepted too small of a gap when executing their turn. Another crash narrative reads:

*Vehicle 1 was traveling west on Rt. 44 when he stated that vehicle 2 pulled out from Mill St. and **cut in front of him**. Vehicle 1 then swerved to the right to avoid hitting oncoming traffic and vehicle 2. Vehicle 1 then ran into a ditch off of Rt. 44, struck a Kahains furniture sign, telephone pole, and street sign. Vehicle 2 operator stated he observed vehicle 1 traveling west on Rt. 44 and **estimated that he had enough time to execute a left turn** onto Rt. 44 heading east. Two witnesses stated vehicle 2 cut off vehicle 1 and caused the accident. Vehicle 2 operator cited for failure to yield.*

In this case, the operator of vehicle 2 explicitly states that they considered the gap available to them, determined it was large enough, and accepted it. The operator of vehicle 1 and onlookers clearly believed it was an insufficient gap. One other crash narrative reads:

*Vehicle 1 was travelling westbound on Washington St., vehicle 2 pulled out of Walker St. without looking, causing vehicle 1 to drive directly into the driver side of vehicle 2. The operator of vehicle 2 stated that **he could see vehicle 1 in the distance and believes that vehicle 1 speed caused the accident**. Operator 2 was cited for 89/8 fail to yield right of way/intersection.*

This case has an added complication that speed may have been a factor, however, regardless of the speed of vehicle 1, the operator of vehicle 2 made the determination that the gap was sufficiently large, when in fact, it was not. These narratives serve as validation that the crashes identified were in fact gap acceptance related and an intersection right of way violation is an effective parameter to identify such crashes.

The analysis of the crash data was straightforward. The driver involvement and citation rates in these gap acceptance crashes were normalized by the size of the respective driving population. The driver populations that were over or under represented were identified.

The final step in the analysis was to compare the gap acceptance behavior with the relative representation in gap acceptance related crashes.

Comparing the results from the gap acceptance analysis and crash analysis the most interesting findings where drivers were making left turns. This is also the maneuver that presents the greatest challenge and danger.

A closer inspection of the data related to driver age was completed, and the resulting percent of accepted and rejected gaps are plotted by gap length in Figure 9. This figure shows that for any length gap the teen driver is more likely to accept it than the adult driver. The critical gap, as depicted in the graph, represents the 50/50 decision point where drivers are equally likely to reject or accept the gap. The critical gap is

significantly shorter for the teen drivers than the adult drivers. Suggesting that teen drivers are more aggressive in the gap acceptance behavior than adult drivers.
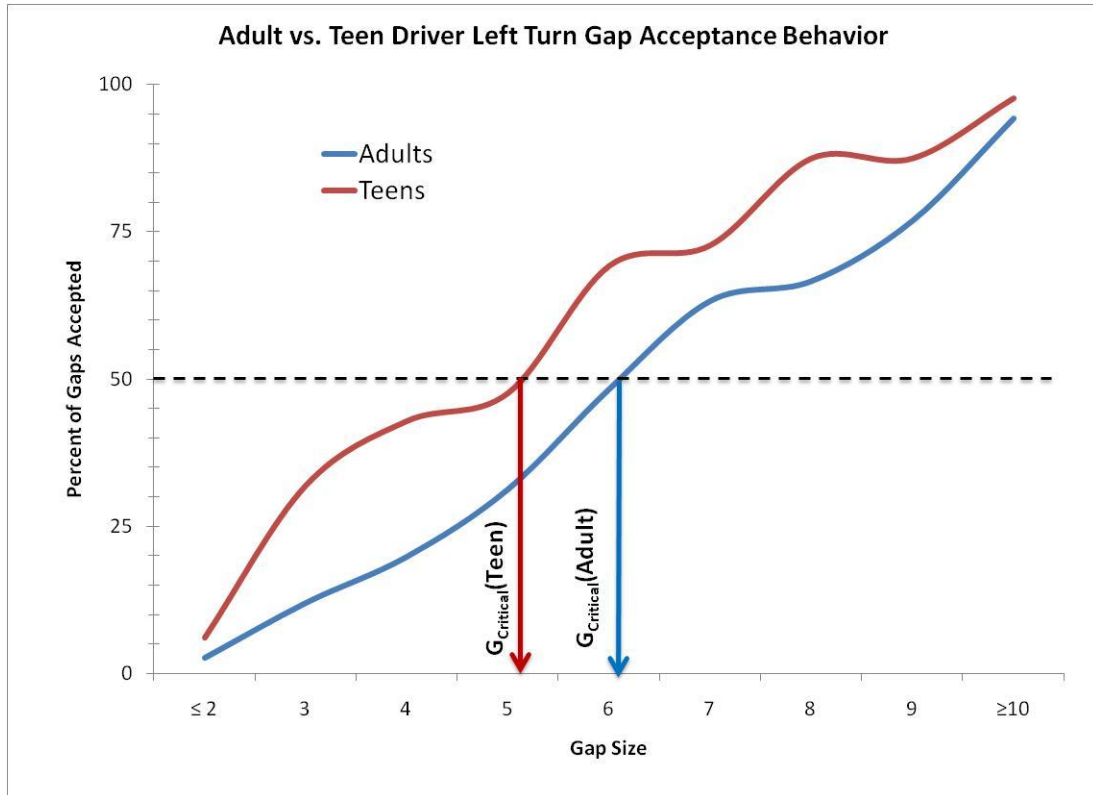

Figure 9. Adult versus Teen Driver Left Turn Gap Acceptance Behavior

Looking specifically at the critical gap, as determined by the Raff Method, there are clear differences in behavior of male and female drivers as well as teen and adult drivers. Table 7 compares the critical gap as determined by the Raff Method by driver gender and age for left turns. The data indicate that male drivers accept smaller gaps than female drivers. This represents more aggressive gap acceptance behavior by the male drivers. The results show that teen drivers are willing to accept smaller gaps than adult drivers, a sign of aggressive gap acceptance behavior. Unfortunately, the relatively small sample of elderly drivers yielded inconclusive results; however studies have shown that elderly drivers tend to be more conservative in the gap acceptance behavior waiting for larger gaps before turning (Zhou, et al. 2010).

Table 7. Left Turn Critical Gap and Relative Involvement in Gap Acceptance Related Crashes by Gender and Age

	Critical Gap	Relative Involvement*
Male Drivers	5.5 s	1.1
Female Drivers	7.0 s	0.9
Teen (under 20)	5.5 s	3.4
Adults (age 20 - 64)	6.5 s	1.0

*% of drivers involvement in gap acceptance related crashes divided by % of driving population

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With the apparent differences in gap acceptance behavior between driver groups, the question is whether some of these aggressive behaviors translate into gap acceptance related crashes. To answer that question, the gap acceptance related crashes were analyzed by driver group. The percentage of each driver group's involvement in the crashes was compared to the group's proportion of the driving population. The resulting metric measures whether the group is over or under represented in gap acceptance crashes relative to the number of licensed drivers in the group; numbers greater than 1 correspond to overrepresentation of a group and values less than 1correspond to underrepresentation of the group. This metric is also presented in Table 7.

These results indicate that male drivers are overrepresented and female drivers are underrepresented, suggesting that the male drivers aggressive gap acceptance behavior may be resulting in gap acceptance related crashes. The comparison between teen and adult drivers are even more striking with the adult drivers being appropriately represented given the number of adult drivers and the teen drivers being overrepresented by more than a factor of three. These results by age group would be even more striking if the vehicle miles traveled were considered as teen drivers tend to drive less than adult driver meaning they have less exposure but significantly more crashes.

CONCLUSIONS

This research initiative represents a promising step in enhancing the transportation professions understanding of gap acceptance behavior.

Using the data set collected in the large-scale field test using the newly developed software package, factors that appeared to affect drivers' gap acceptance decision, and had clear implication on safety, were identified. Different driver groups, specifically different age and gender groups, displayed different gap acceptance behavior. Passenger presence and time of day also appeared to affect drivers' gap acceptance decisions. The factors that had the greatest affect of gap acceptance behavior were the presence of a queue behind the driver, wait time, and number of gaps rejected. These factors, relating to drivers feeling pressure, impatience, and frustration, resulted in drivers accepting shorter gaps and sacrificing a degree of safety to execute their turn.

Using the process described in this research initiative, "gap acceptance related" crashes were be identified and analyzed. These results of the analysis of gap acceptance related crashes showed strong connections to the results of the gap acceptance analysis. Driver groups displaying more aggressive gap acceptance behavior, male drivers and teen drivers, are overrepresented in gap acceptance related crashes. Understanding these connections could lead to more targeted solution to the gap acceptance related crash problem. The gap acceptance related crash problem is a complex one that requires further investigation and a multi-faceted mitigation approach if significant improvements in safety are to be made.

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